ON AN ALTERNATIVE APPROACH TO CYBERNETICS

G. K. AGGARWAL*

ASSTT. PROF. INSTITUTE OF ARMAMENT TECHNOLOGY, POONA-12, INDIA

(*Received September 16, 1967, Resubmitted April 8, 1968*)

ABSTRACT. It is pointed out here that an approach to the types of problems falling in the domain of cybernetics should not be basically in terms of searching for rigorous control and communication processes because growth or evolution in animal systems utilise control and communication mechanisms only as guiding factors and not as governing factors. An alternative approach should be developed to study animal systems in terms of inherent constraints and interactions rather than in terms of controls and communications.

INTRODUCTION

Norbert Wiener had defined cybernetics as control and communication in animal and machine. Until recently rigorous methods of analysis and synthesis of control systems and communications were applied to the study of behavioural aspects of animal systems and machines. It now began to be realised that cybernetics has not been able to get recognition as a branch of learning either like the physical sciences or like the biological sciences. Unlike physical sciences, cybernetics does not have the facility to deal with idealised standard models on which to carry out further refinements, since every animal or animal system it examines is unique and any idealised simplification would lead to serious misconceptions. Equally, unlike biological sciences cybernetics has tended to give less importance to the basic character of the constituent hardware, its organism and growth, which ultimately put severe limitations on the utility and even validity of the results arrived at by use of rigorous mathematical tools of control and communication. Since 1962 onwards the aspect of incompatibility, even if superficial, of rigorous mathematical analysis or synthesis to the study of biological systems in which the decisive role is played by the cellular organism rather than the organs as such, is often being brought to light but still the basic notion continues to be held in favour of considering a biological system as subject to rigorous control processes, however complex and sophisticated, rather than as systems free to perform, grow and evolve in any manner whatsoever, subject only to certain limiting constraints. Also emphasis has not yet shifted in the thinking on the subject from communication to interaction between various constituent organs of a system, the latter requiring consideration of the semantic aspect of information in addition to its syntactic aspect.

**Present address* : Defence Electronics Research Laboratory, Hyderabad-5, India

In the following section this alternative approach is explained and a system function, the sort of which would need examining in connection with any cybernetic model, is also outlined.

AN ALTERNATIVE APPROACH

It is seen from the preceding section that the approach of cybernetics to animal systems is rigorously through the concepts, theories, and practices in the topics of control, communication and machine. Since all these three topics are developed mathematically, it follows that the cybernetician implicitly visualises that an animal system follows a very rigorous, though complex and sophisticated, mathematical logic in its development and functioning. Consistency within itself is the essential characteristic of any mathematics. Thus if any problem is posed, which has not appeared earlier, a mathematician is compelled to suggest solutions based only on such lines as are consistent with what all other things exist in the domain of mathematics. The solution suggested will be either a particular case of a general result or will reduce to many known results in particular cases. Particular cases may mean particular forms or values of stimuli, or particular forms or values of parameters. This is not the case for animal systems. Any mathematics, if that is to be applicable to animal systems, must admit inconsistencies and contradictions as part of its characteristics and yet be capable of presenting in perspective, rigorously correct and accurate picture of an animal system both with a view to explaning its observed performance and to predicting its likely response to an environment and stimulus. One needs to develop a new mathematics that might be called BIO-MATHEMATICS. That mathematics should should be such that any premises made under it should be derived from the knowledge of biology and not in a manner, such as the present one, which does not allow that mathematics to be applied to any problem without prescribing its own logical rules and conclusions on the systems under investigation.

The concepts of control, communication, and machines were applied to the study of the functional behaviour of animal systems. Once, however, the functional behaviour is sought to be explained on the basis of the development of cellular organisation, these concepts may not hold ground. At the level of cellular organisation, it is not the controls but the constraints which are operative and effective. There is no definite control mechanism, however complex and elaborate one may try to visualise it, at that level, that is used for self-organisation or for evolution. Therefore, the pattern of self-organisation or of evolution could not not be contained in the first place in the egg nor at any subsequent stage in the development of the organism. Distinction may be made between self organisation and evolution. The former refers to reorganisation within the same species without adding new types of constituent parts while the latter refers to evolution from one species to another with possible addition of new types of constituent parts.

Let us state the point as follows : Given an animal system, it may have to face two types of situations. If the situation is such that its demand can be successfully met by the system at the behavioural level, the system meets it by trying a variant of a response either known to it earlier or used by it earlier and in this mode of trial any abnormalities or patterns inherently embedded in its cellular organism also play a decisive role. To such types of situations faced by a system, the cybernetician could apply a perspective mathematics though not a strictly pragmatic mathematics. If the situation is one which is in the nature of a challenge to its survival as an organism, the system first tries to effect certain self-organisation, the rules for which are not embedded in its original development, while still remaining a member of the same species. If the situation is so severe that by mere self-organisation the system cannot survive it as an organism, there is one of two alternatives available to it, either to perish, or to evolve into a different species. Upto the level of the first type of situations we may concede that the system is open to energy but is closed to information. At the level of self-organisation also we may say that generally speaking, though not strictly speaking, the system is closed to information. When it comes to the level of having to develop into a new species for survival, the system shall perish if it is not open to both, information and energy. The rules of transition, if any, from the given species to a new one which could survive the situation, are not embedded in the original egg of the given organism. The evolution is not subject to any control but is certainly subject to the constraints of the given species, the given situation, energy and information available. Evolution is not a controlled but a free phenomenon occuring under certain constraints. The cybernetician shoud, therefore put emphasis on the study of the nature of constraints rather than the nature of control Given certain constraints, the system could evolve into one of the many, finite or infinite, new systems, which one it is going to evolve into cannot be predicted with certainty. Only an evolving automaton as against a simply growing automaton, can claim immortality, that is, a system to claim immortality should be open not only to energy but also to information. A role of the cybernetician would be to obtain information on the constraints from the biologist and to show, if possible, whether the number of new systems into which the given system could evolve if it must survive a given situation, which it cannot survive without evolution, is finite or infinite.

If F is the given system, E the energy and I the information available to it, M the situation faced by it , S its survival, then the next species into which it will evolve could be expressed as a function $\phi\ (F, E, I, M, S)$ of all these entities, where ϕ itself should have the property of evolution.

Case—1 :

If $\phi\ (F, E, I, M, S)$ exists for any values of E under the condition that either $I = 0$ or $\partial\phi/\partial I = 0$ then ϕ must be either F itself or a variant form of F. By existence of ϕ we mean the existence of a functional relationship ϕ (F, E, I, M, S) for at least one value of S lying between $0 < S \leqslant 1$. If not, ϕ must perish - i.e. for no value of E is there, a functional relationship possible between F, E, I, M, S for any value of S except hypothetically, $S \leqslant 0$. By $\partial\phi/\partial I = 0$ we mean that even if an information I is available to the system, it is unable to utilise it. Certainly, both E, $\partial\phi/\partial E$ should be non-zero.

Case— 2 : .

For all $E, I, \partial\phi/\partial E$, $\dfrac{\partial\phi}{\partial I}$ to be non-zero, ϕ must exist for any M, and be different from F. In general, ϕ can have more than one form, the number of possible forms may be finite or infinite. If ϕ does not exist for any M, even under non-zero values of $E, I, \partial\phi/\partial E$, $\dfrac{\partial\phi}{\partial I}$, the system must perish.

Note—1 :

For both the cases, $\dfrac{\partial\phi}{\partial M} \neq 0$ because $\partial\phi/\partial M \quad 0$ is a triviality.

Note—2 :

In both the above cases, the resulting system ϕ must possess all the properties of the function ϕ.

What the above symbolism is meant to convey is : For those situations M, which the system can survive without additional information, it need not evolve and for other situations M in which the system cannot evolve even with the availability of additional energy and information, the system will perish. For other cases, falling somewhere between these extremes, the system should evolve into a new system ϕ which in turn should be capable of exhibiting evolution. Alternatively one could suggest a function ϕ which should show singularities in the region $0 < S < 1$ with $E = I = 0$ and one or more of those singularities should resolve into a multivalued function by giving nonzero values to E and I. It is left as an open question whether a singularity should resolve for all values of E and I, or for only discrete values of E and I.

On the question of communication, it must be emphasized that it is the mutual interaction among the cells and the successive resulting patterns that influence the development (growth in size and complexity) of the organism. It is, therefore, necessary that present theory of communication is developed to include in its scope not only the technical but also the semantic and effectiveness problems. There are formidable difficulties in so extending the scope of information theory but new concepts like negative-information and relative-information should be developed. The concept of channels should be extended to include the spread of influence as a field effect so that it could be applied to unlocalised automaton

Investigations into coding techniques should draw upon the biological knowledge, and research at the level of genes and cellular organism.

To bear any close resemblance to animal systems, an automaton should be of an unlocalised type which should be floated to grow and develop rather than be designed with any rigorous design procedures. Control should not be the basis of performance of such automata but should be incorporated only as a special feature of the automata. The structure as well as performance should be expressed in terms of the basic constraints on the materials the automaton is composed of and it should be stipulated that it is capable of any performance so long as the demands put on the materials can be met. Search for algorithms should extend to working out the possible mechanisms by which an unlocalised automaton may develop and perform under the minimal constraints imposed by the characteristic limitations of the constituent materials and to bring out the survival limits of the automaton. The question whether complexity of structure can compensate for lesser versatility of constituent materials should be examined and answered. The concepts of a decision procedure and an effectively calculable function must be extended, possibly with the use of a concept of negative information, because one knows that one can survive a situation even under a state of ambiguity that is similar to the absence of any decision procedure or effectively calculable function. Uncertainty must be regarded as an indispensable part of the conceptual framework within which the modern cybernetician is to work. But it must be said that the significance of Turing machines cannot be belittled since it does succeed in extending the effectiveness of a finite automaton to that of an infinite or growing automaton in a manner similar to an animal system since the infinite character of an animal system behaviour does derive to some extent from the infinitum of data that it receives all the time, and processes.

CYBERNETICS REDEFINED

In any case the cybernetician must be very careful in applying the rigorous techniques to animal systems and must develop an integrated conceptual and methodological framework in order to benefit by or contribute anything worthwhile to the study of control and communication in animal and machine. He may redefine cybernetics as the study of constraints and interaction in animal and machine.

REFERENCES

Alt, F. L., 1961, *Advances in Computers*. Vol. II, Academis Press, N.Y.

Apter, M. J., 1966, *Cybernetics and Development*. Pergamon Press, London.

Arbib, M. A., 1964, *Brains, Machines and Mathematics*, McGraw Hill Co. Inc. N.Y.

Norbert, W., 1962, *Cybernetics*, John Willey and Sons, N.Y.